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TRISONIC GASDYNAMIC FACILITY USER MANUAL

Revision 1 of TM 73-82 FXM

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Aeromechanics Division
Flight Dynamics Laboratory

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Approved for public release; distribution unlimited

FLIGHT DYNAMICS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
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FOREWORD

This Manual is a revision of the Trisonic Gasdynamic Facility User Manual (TM 73-82 FXM) published in 1973. The facility has since undergone numerous modifications. Improvements are still being performed as an on-going program to provide the highest quality testing possible. This document gives a detailed explanation of the facility's actual capabilities and test procedures. The Aerodynamics and Airframe Branch of the Aeromechanics Division is the controlling agency that schedules tests for the Trisonic Facility. Including the expertise of Experimental Engineering Branch, an abundant amount of assistance is available to answer any questions or help with any problems in reference to this facility. Please feel free to direct any questions to the Experimental Aerodynamics Group at the address given in this report.

This report has been reviewed and is approved.

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I. INTRODUCTION

This brochure was prepared in the interest of outside contractors and in-house Air Force personnel to familiarize them with the capabilities of the Trisonic Gasdynamics Facility (TGF) located at Wright-Patterson Air Force Base. It includes a description of the facility, the type of data reduction available, the capabilities of the wind tunnel, and information for the user.

The two-foot Trisonic Gasdynamics Facility is operated by the Aeromechanics Division of the Flight Dynamics Laboratory, Air Force Wright Aeronautical Laboratories. The facility staff is experienced in a wide variety of wind tunnel testing. Model design personnel are available for all phases of model design and installation. Consultation is also offered on pretest planning, test set-up, test operations, and post-test evaluation. All wind tunnel personnel have Secret or higher clearances.

For further information relating to visits or test scheduling, contact:

Flight Dynamics Laboratory (AFWAL/FIMM)
Air Force Systems Command
Wright-Patterson AFB, OH 45433
Telephone: AV 785-4052
Commercial (513) 255-4052

II. DESCRIPTION OF FACILITY

The Trisonic Gasdynamics Facility is a closed circuit, variable density, continuous flow wind tunnel capable of operating at subsonic, transonic, and supersonic speeds through a range of Mach numbers from 0.23 to 3.0 (Fig. 1).

The two-foot subsonic test section can provide Mach numbers from 0.23 to approximately 0.85. The maximum Reynolds number per foot that can be achieved is 2.5 million. The maximum dynamic pressure for the subsonic section is 350 PSF.

An insert for transonic testing reduces the test area to 15 x 15 inches. This insert has an option of either two or four variable slotted walls allowing the wall porosity to be varied between 4 and 12%. The Mach number range for the transonic test section is 0.3 to 1.0. This test section can achieve a Reynolds number per foot of 8 million and a dynamic pressure of 1400 PSF. Installation of the transonic insert requires eight hours (Fig. 2 & Fig. 3).

The two-foot supersonic test section operates at discrete Mach numbers of 1.5, 1.9, 2.3 and 3.0 through the use of interchangeable fixed nozzle blocks. These blocks have a maximum Reynolds number per foor of 3 to 5 million with a maximum dynamic pressure ranging from 600 to 1000 PSF. Installation of these blocks requires 2 to 4 hours (Fig. 4).

An auxilliary air system for the tunnel has been installed to accommodate both blowing and suction systems. A 500 PSI high pressure air supply is available at the test section to simulate model jet exhaust or other blowing requirements. This apparatus can provide air at 5lb/sec mass flow and a temperature of up to 1000°F. Likewise, a vacuum line is available for simulation of model inlet flows or other suction requirements.

The electric drive system for the TGF consists of a 5000 horsepower synchronous motor and a 3500 horsepower wound rotor induction motor coupled through a double input single output 3.28:1 gear box. The 3500HP wound rotor motor's speed is controlled by a liquid rheostat, and has sufficient torque to bring the combined system up to the synchronous speed of 3600 rpm. When striving for maximum compressor performance at low densities, an overspeed of 3800 rpm can be achieved with the 3500HP motor alone.

The air flow is propelled by an Allis Chalmers VA 1310 axial flow compressor with a maximum compression ratio of 4.26:1, at a flow rate of 160,000 CFM. The compressor is a ten stage 50% reaction type with variable stator blades.

The compressor is primarily driven at constant speed (3600 rpm). Pressure rise is controlled by hydraulically actuated stator blade stages. The facility operator has instantaneous control by means of individual or simultaneous actuation of all stator blades. This feature renders rapid and sensitive control of flow in the test section.

Temperature equilibrium is maintained in the facility by water cooled heat exchangers located in the stagnation section. Two sets of heat exchangers are used, one each in the upper and lower legs of the facility. The water is supplied from a 432,000 gallon spray pond located adjacent to the facility complex. Stagnation temperature in the facility is maintained at $100^{\circ}F$ by this system with an accuracy of $\pm 1^{\circ}F$. Stagnation pressure is automatically controlled to within $\pm$ 1 psf at any selected value from approximately 100 to 4000 psf, depending upon Reynolds number desired.

A honeycomb and screen arrangement is located in the 8 x 8 foot stagnation section to minimize turbulence in the test section.

The test section has sidewalls which can be taken off in 20 minutes for removal and installation of nozzle blocks, transonic test section insert, and test models. The sidewalls are equipped with 3 inch spacers which are added during transonic testing to equalize the plenum area around the test section insert.

A pair of 28 inch diameter hinged windows are mounted on the test section sidewalls. These windows can be opened quickly to allow easy access to the models for configuration changes. Also, the two optical quality glass windows allow the use of schlieren and motion picture photography and laser velocimetry.

The main model support system for the TGF is a rack-mounted fifty-inch radius crescent. The position and angle of the crescent are displayed on the operator's console to an accuracy of 0.01 degrees. The center of rotation is the center of the test section viewing window. The pitch range is from -1 to

+18.5 degrees for the subsonic and supersonic test sections. The range decreases to -1 to +12 degrees for the transonic section.

A variety of sting extensions are available (including an offset sting, Fig. 5) for attachment to the crescent. The main support has a remotely controlled roll capability of -90 to +180 degrees, with an accuracy of $\pm$ 0.005 degrees. This combined pitch and roll capability provides model angle of attack and yaw attitude variation while maintaining flow in the tunnel.

Another support has the capability of transversing horizontally a total of 18 inches to an accuracy of $\pm$ 0.001 inch. This feature is useful for pressure and temperature probing. A computer controlled, three-dimensional traversing capability (axial, vertical, and lateral) has also been provided.

Various types of strut supports are available or can be constructed for special model installations. Two attachment points are available. One is located at the four inch transition section located between the test section and the diffuser. The other utilizes the crescent opening area when the crescent has been removed. No attachment point exists in the test section area.

For half span and two-dimensional test model installations, two additional 28 inch window frames are available for installation of blank aluminum plates (Fig. 6 & Fig. 7). These aluminum plates are used with the two foot test section. Pressure, temperature, and blowing or suction apparatus can be used with this installation. In the 15 x 15 inch transonic test section, two-dimensional tests can be conducted in the present slotted test section by replacing the center test slat viewing windows with metal pass-thru inserts. The models are attached outside the test section to the support structure. An alternative arrangement uses two solid sidewalls (with top and bottom slotted walls) and an 11.426 inch diameter removable split-window in each sidewall to provide an external support for the two-dimensional model. The second arrange-

ment has a 12.125 inch square removable plate area in the sidewalls which can be replaced with a porous plate for boundary layer control.

An adjustable diffuser is employed in the TGF circuit to increase the efficiency of operations by providing a favorable pressure recovery over a wide range of tunnel conditions. By utilizing the adjustable diffuser as a remotely controlled restriction device, flow through the test section may be completely cut off and directed through a bypass system while keeping the drive train and compressor on line. Thus, stagnation and atmospheric pressure can be equalized, making the test model accessible. This action provides a savings of at least 20 minutes per model change by not having to stop and restart the drive train. The diffuser also provides access to the pitch crescent area through removable ports in both outer housings, and in the first section of the adjustable sidewalls (Fig. 8).

The bypass system consists of a twenty-inch pipe with a fast action pneumatic valve. The bypass line extends from the 8 x 8 foot stagnation section ahead of the test section to the aft end of the diffuser section just ahead of the protective grid and turning vanes. The combined flow through the test section and the bypass hold the compressor pressure ratio well below that required to establish the flow, even when rotational speed and stator blade setting are sufficient for supersonic flow. To establish the flow in one or two seconds, the high speed bypass valve is closed. This technique of rapidly starting flow and dropping out flow has drastically reduced dynamic loads on the models. The second use of the bypass system is in conjunction with the adjustable diffuser for model changes (as explained above).

The dryer system employed in the TGF in order to obtain a dew point necessary to prevent liquefaction in the test section is a full flow dryer system utilizing molecular sieve as an agent. It can effectively be used at temperatures up to 200°F. No trouble is encountered in obtaining dew points

as low as -35°F with this system. This system continuously recirculates a portion of the air within the facility when operating at all Mach numbers.

III. PERFORMANCE RANGE

A description of various tunnel operating capabilities in terms of pressures, Mach numbers, and Reynolds numbers is presented in the following graphs:

Figure 9 - Performance chart for the subsonic test section

Figure 10 - Subsonic Mass Flow

Figure 11 - Performance chart for the transonic test section

Figure 12 - Transonic Mass Flow

Figure 13 - Performance chart for the supersonic test section

Figure 14 - Supersonic Mass Flow

Figure 15 - Model blockage data

Figure 16 - Transonic centerline Mach number distribution

IV. MODEL INSTALLATION

The calibrated rhombus boundaries for each of the nominal supersonic test Mach numbers is shown in Figure 17. Within these boundaries, flow expansion to design supersonic speed is achieved. Flow inclination with respect to nozzle axis has been found not to exceed 30 minutes in either pitch or yaw within the rhombi. Nozzle axis station 88 simultaneously represents the centerline of the 28 inch diameter view window and the rotation point for the pitch mechanism through the point of usual model sting attachment.

V. INSTRUMENTATION

Facility instrumentation is readily available for any conventional type of testing. Special instrumentation can be acquired for extreme or unusual conditions.

Strain gauge balances are primarily used to obtain force and moment data. There exists a sizeable inventory of both force and moment balances. The

balances are of the six component, internal type designed to indicate the aerodynamic loads through deformation of the balance load sensing elements. The load sensing elements have applied to them one or all arms of a wheatstone bridge arranged in such a manner as to give an electrical signal proportional to the deformation and ideally the load.

The primary pressure sensing intrumentation consists of differential pressure transducers of various ranges from 2.5 lb/in^2 differential to 250 lb/in^2 differential. The pressure transducers are used to measure one pressure per transducer, or in conjunction with scanivalves to measure as many as 48 pressures per transducer. The transducers can be referenced to a variable pressure from 0 to 14.7 psi or to any other pressure channel being used.

For measurement of velocity and turbulence, a two channel TSI hot wire anemometer system is available. The system includes a hot wire anemometer, voltmeter, and linearizer. Some probes are on hand, but in general, probes must be specially purchased for a given test.

Data is collected and recorded by a Hewlett-Packard 2100S micro-programmable computer with 64K bytes of core memory through a software controlled, 64 channel, single ended multiplexer and a 12 bit/30,000 sample per second analog to digital converter. All necessary electronic equipment (power supplies, signal conditioners, amplifiers, etc.) is available to electrically condition the previously mentioned instrumentation such that their respective electrical signals can be processed by the 64 channel multiplexer. After the data has been read by the computer, further data processing continues on line under program control. The primary language utilized by the system is FTN 4. Processed data is typically output on a 9 track digital magnetic tape, 5 mega-byte moving head disc, 200 lpm/132 character line printer, and/or an 8.5 x 16 inch X-Y digital plotter (Fig. 18 & Fig. 19), and can be examined during the progress of the test as each test point is recorded.

Optical test equipment includes schlieren and motion picture systems. A z-type schlieren system is used to view flow patterns in the facility. Black and white or color photographs can be taken. The basic setup consists of two mirrors, thirty-six inches in diameter with fifteen foot focal lengths. The facility test section is located at the mid point between the two mirrors which are forty-six feet apart. Sixteen millimeter motion picture photography up to 11,000 frames per second (22,000 split frames) is available for oscillatory flow patterns. To enhance surface flow visualization, the model or parts to be observed can be coated with a special coating of oil which enables photography without special illumination. Boundary layer condition studies, along with shock wave location and strength conditions could also be observed in the facility by the use of a temperature sensitive liquid crystal coating applied to the model surface.

VI. INFORMATION FOR THE USER

A prospective user can generally establish from the information in this manual whether the TGF is suitable for proposed tests. Although the user can make a preliminary evaluation, constant changes in the facility capability and the unique requirements of particular tests always necessitate a meeting between user and laboratory personnel. If it appears that the user has a test requirement that can be fulfilled with the facility's present or potential test capabilities, he should contact the TGF staff via the address given in the introduction. After initial contact, the Aerodynamics and Airframe Branch will arrange a preliminary planning conference and supply detailed administrative and policy information.

Prior to the preliminary conference, a Flight Dynamics Lab Test Director and Project Engineer will be appointed for each test. The test director has

primary responsibility for conducting the test program. The following information should be prepared for discussion and review at the initial meeting:

1. Objectives and scope of the porposed test.

2. Preliminary test plans describing the desired test conditions, test configuration, instrumentation, data acquisition and reduction, and test support requirements.

3. Scheduling considerations.

After a detailed study of the above information, the TGF staff will recommend how and when the proposed test could be accomplished.

If after the initial planning phases and evaluation, the user (and sponsor) decide to proceed with a formal test request, the following procedures will apply:

1. The user shall prepare and coordinate with the sponsor a test requirement document that will contain test objective, scope, desired test program and schedule, model description, instrumentation, and data acquisition and reduction requirements to the test director assigned to the test.

2. The sponsor shall prepare a formal test request that, after acceptance by FDL based on national priorities, authorizes the expenditure of resources on the proposed test. Components of the Air Force will normally formulize the request using a Project Order, AF Form 185, in accordance with AFSCR 172-2. Department of Defense components outside of the Air Force will request a test with a Military Interdepartmental Purchase Request, MIPR, in accordance with ASPR-5. Other governmental agencies will formulize a request with appropriate forms that authorize the expenditure of resources against a fund citation. In accordance with AFR 80-19, any commercial nongovernment contractor desiring the use of Air Force facilities and supporting services must seek as a sponsor a Federal Executive Agency whose regulations require such testing or whose direct interests are most directly aligned to the unique testing being proposed. All formal requests including appropriate fund citations will be forwarded to the Aerodynamics and Airframe Branch, Flight Dynamics Laboratory.

After the decision to proceed with a test program has been made, a detailed test plan will be accomplished. Early definition of the test plan, and a close working relationship between sponsor and user project engineers and the FDL project engineer, will insure the success of the test program. The test plan should include, but should not necessarily be restricted to, the following:

1. Purpose and scope of test.

2. Detailed information on test requirements including test hardware variations, test procedures, and safety precautions.

3. Test matrix which should include the rationale for the order of testing.

4. Instrumentation requirements including range, response, accuracies, calibration, etc.

5. Location and notations for sensors.

6. Detailed data acquisition and reduction requirements.

7. Test hardware description, configurations, and specifications.

8. Detail drawings as required.

9. Equipment furnished by the user.

10. Test model and support hardware and delivery schedule.

Although there is no hard and fast rule for model and probe deliveries, it is important to the success of a program that the deliveries be made at least a month in advance of installation of the model in the TGF.

After model and probe installation and checkout, the test series will begin. Engineering coordination can be best accomplished if the sponsor project engineer and user project engineer are present during at least part of the test program. In cases where it is not possible for sponsor or user personnel to be present, the test director will attempt to maintain close liason by telephone. Also, if the model system or associated hardware are unusually complex, or if the user wishes to install his own cameras or specialized instrumentation, it is suggested that appropriate engineers and technicians be present during the test series. For the period of the test program, a work area for sponsor or user representatives can be provided by FDL.

It is the responsibility of the TGF staff to safeguard personnel and property from hazards associated with the operation of the facility and test hardware. The user is responsible for providing safe and adequate test articles in accordance with the design principles and safety factors provided

by the Test Director. Test article designs and stress analysis will be forwarded to the test director for review and approval prior to fabrication. If upon inspection, the test hardware is found to have deficiencies affecting proper installation, performance, or safety and which cannot be corrected prior to the scheduled test date, the test director will determine if the test should be rescheduled.

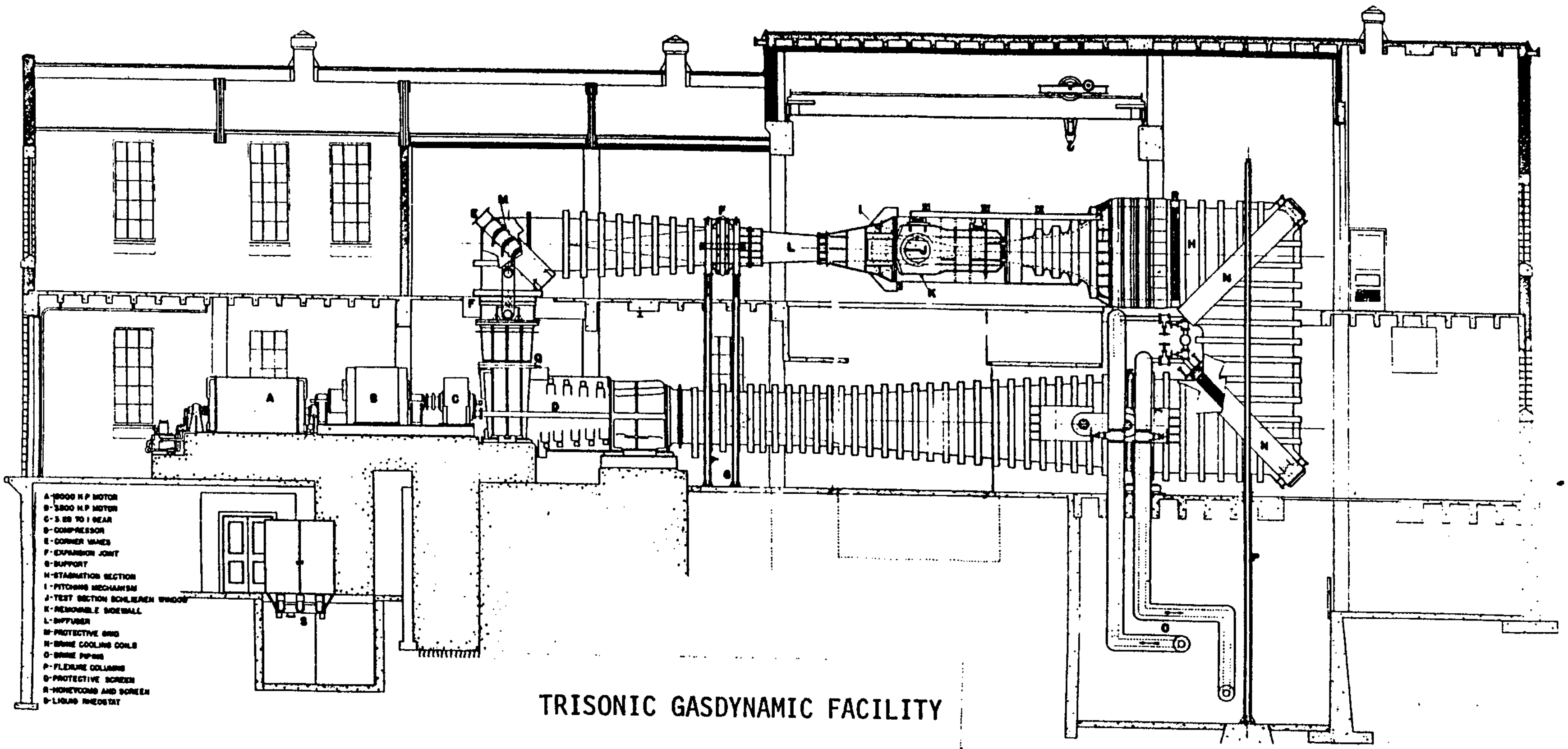
In the event of a malfunction of test hardware, the test director will decide if the test should be continued, extended, or rescheduled based on the requirements of the sponsor, other scheduled tests, FDL policy, and safety.

After completion of the test, it is important that FDL, sponsor, and a user personnel review the test objectives that have been accomplished. Also, opinions of both the sponsor and user are requested regarding improvements that might be made for future tests of a similar type. It is hoped that by a continuous exchange of ideas between FDL, test sponsors, and users, the test procedures and capabilities of the TGF may be further improved.

VII. CONCLUDING COMMENTS

The operational performance data and characteristics of the TGF demonstrate a superior capability for the low cost study of subsonic, transonic, and supersonic aerodynamic testing of small-scale models. Nevertheless, continuing refinements are being sought, and comments and suggestions that might help improve the facility's capability, the services rendered by the staff, or the information given in this manual are solicited.

Visits to the TGF can often be scheduled to permit observation of a test run. For further information concerning the facility or group visits, please call Area Code 513-255-4052 or Autovon 785-4052.



TRISONIC GASDYNAMIC FACILITY

Fig 1

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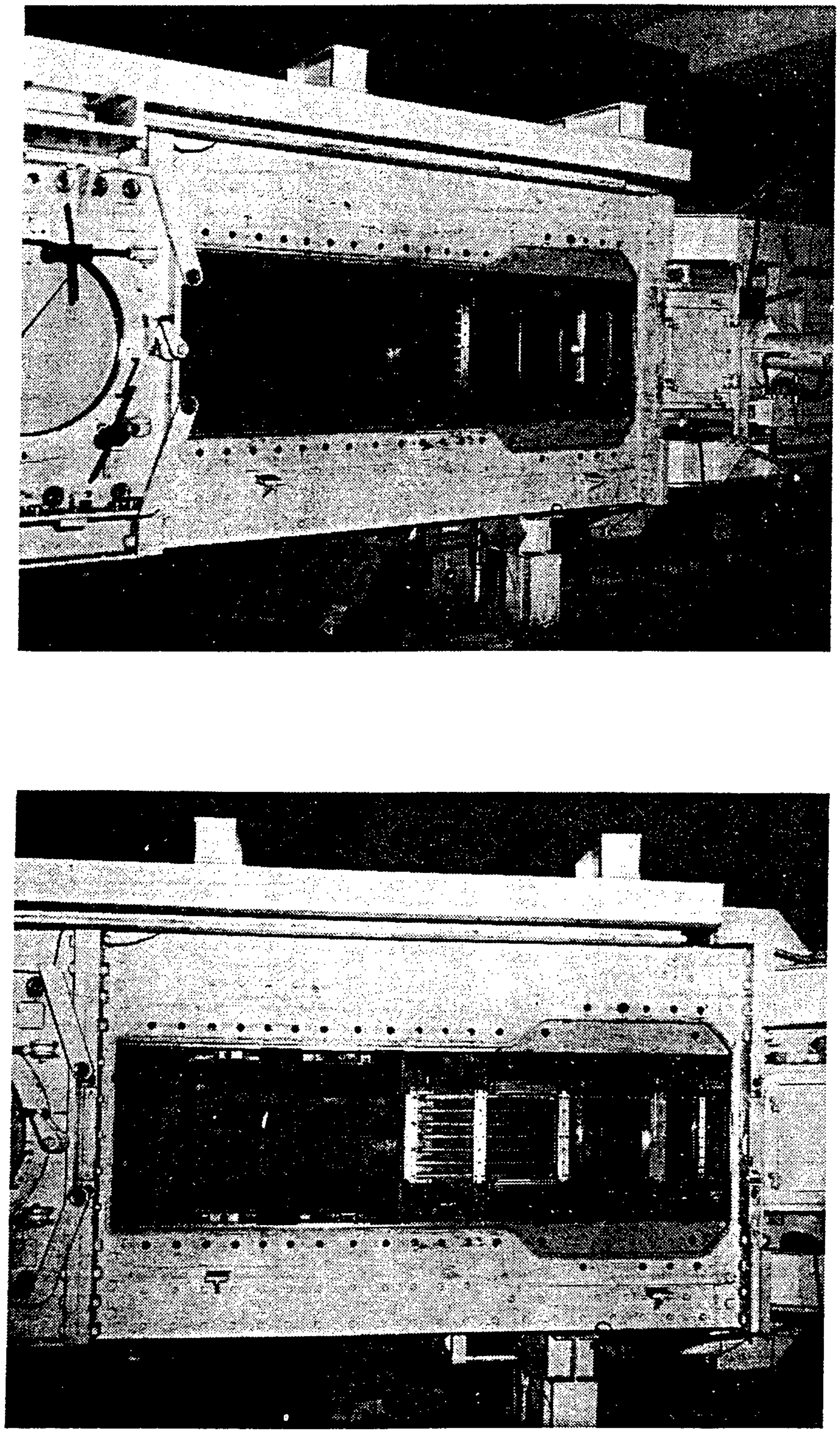


15X15 TRANSONIC TEST SECTION INSTALLATION

Figure 2

TRANSONIC TEST SECTION

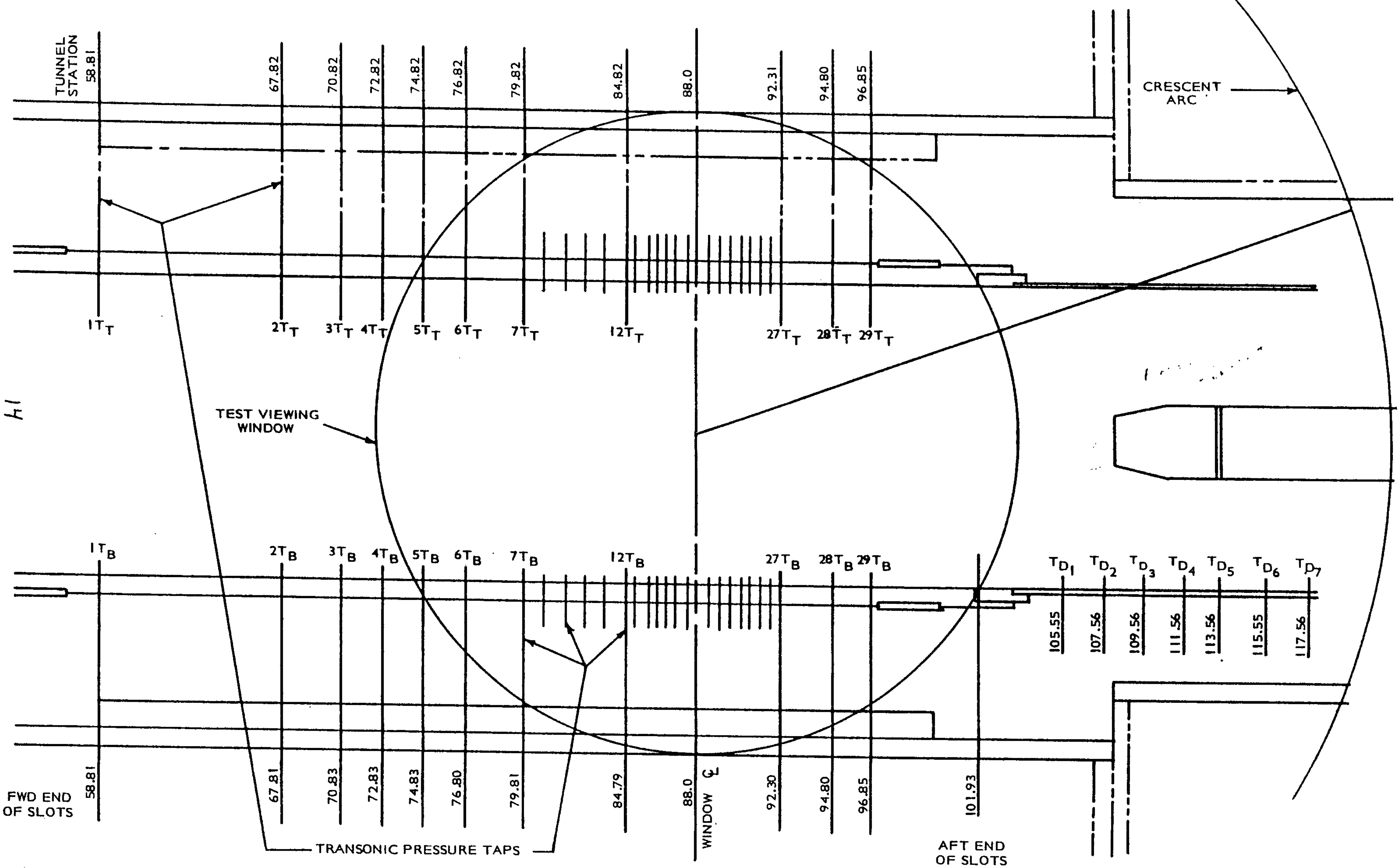
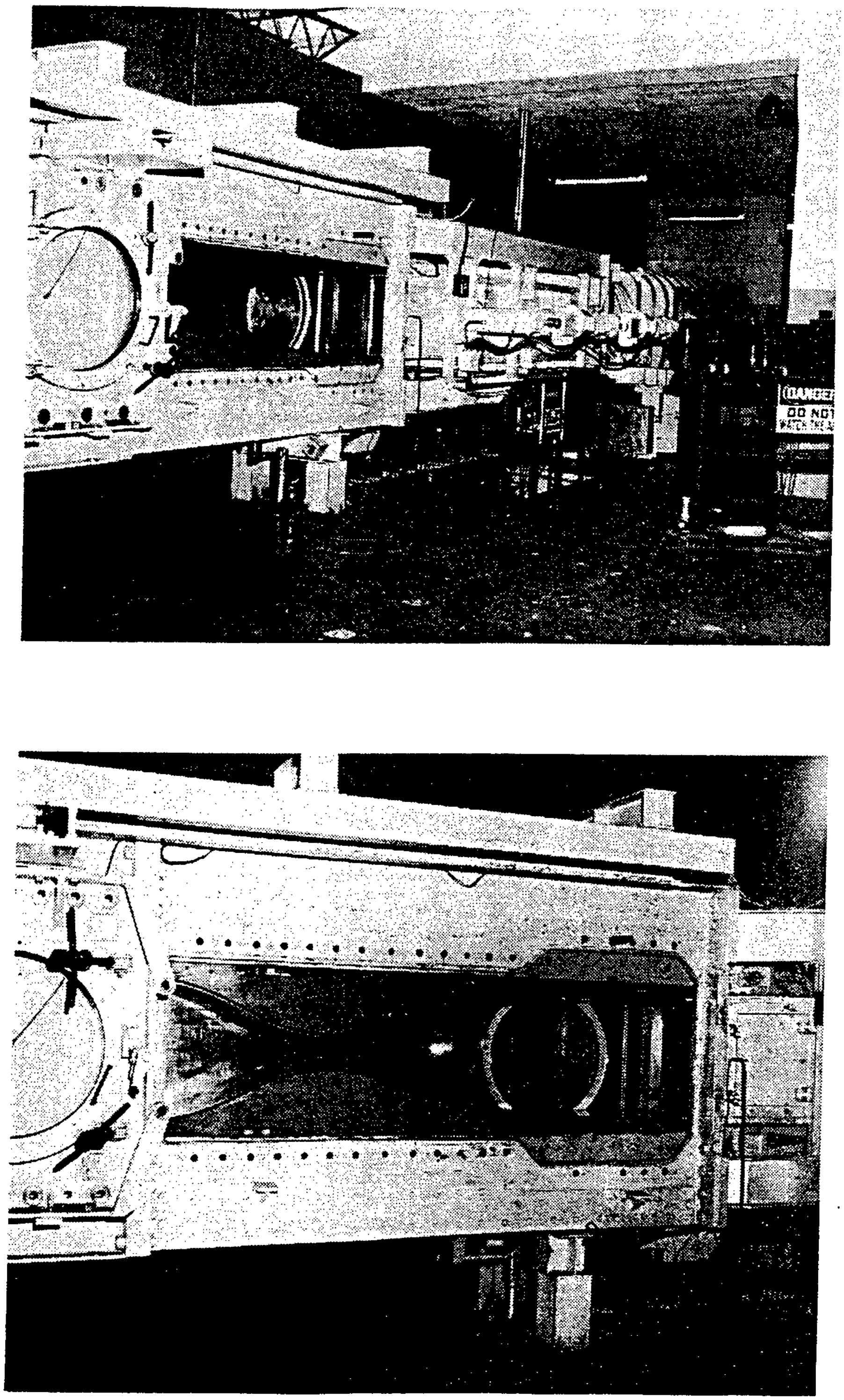
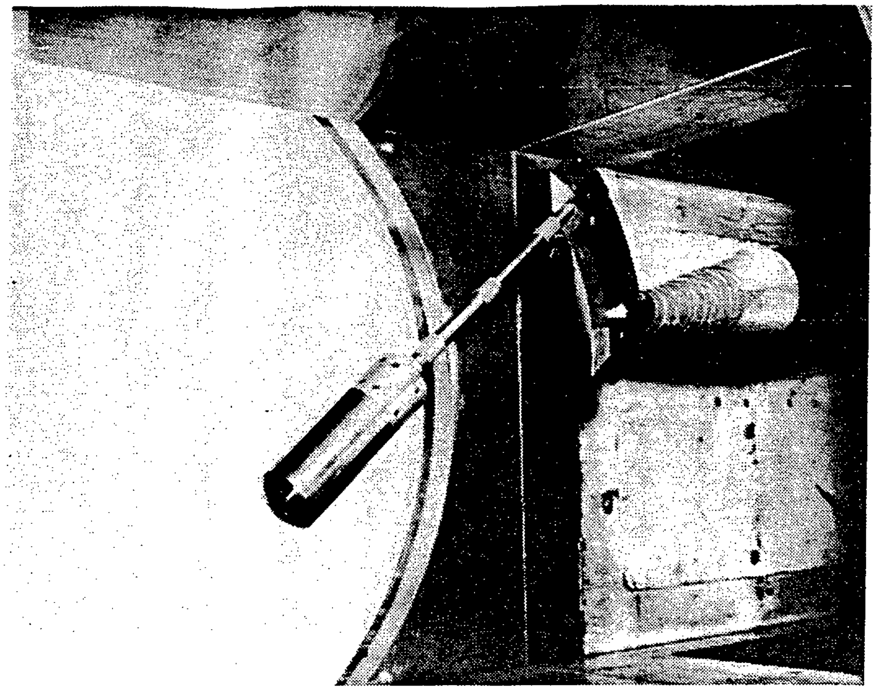


Figure 3



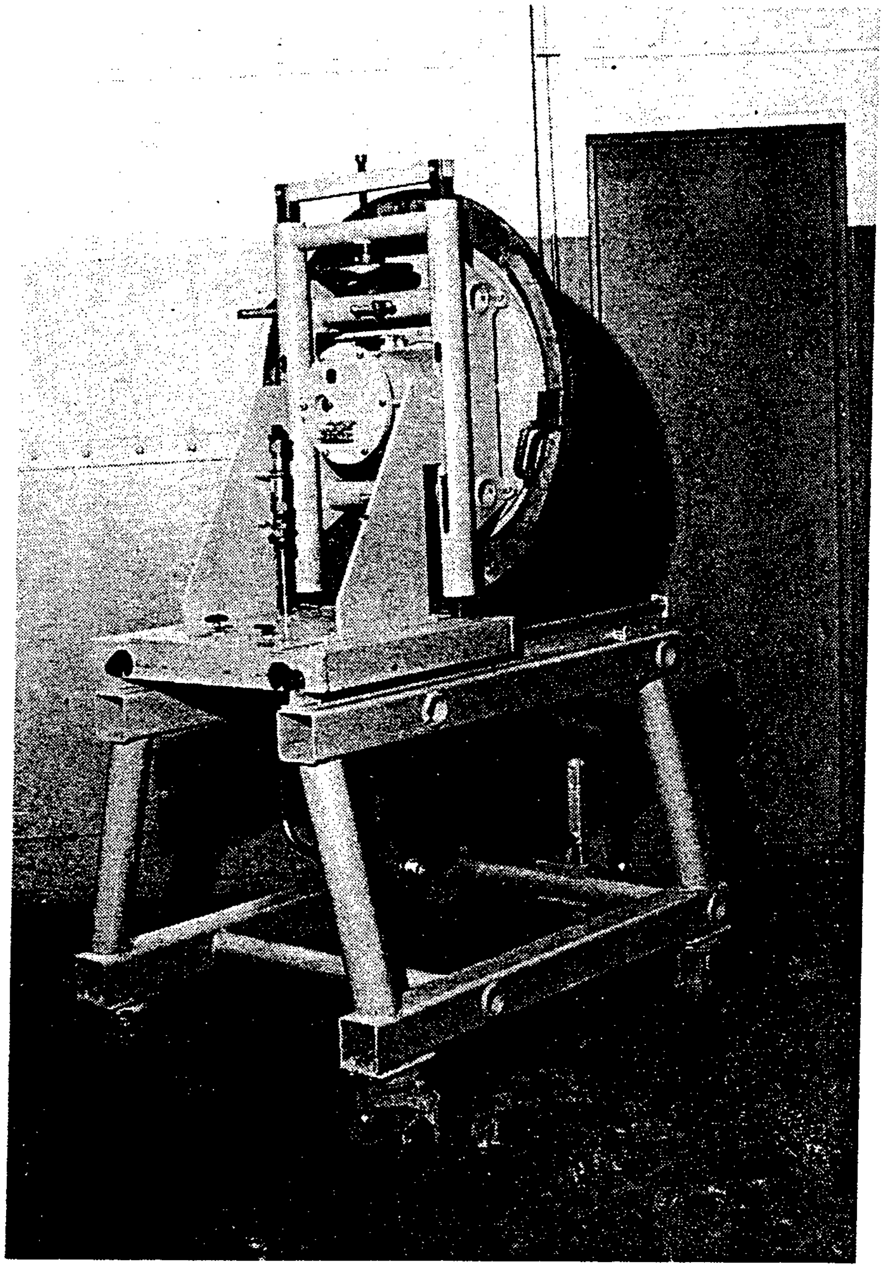
TGF NOZZLE BLOCK INSTALLATION (MACH 3.0)

Figure 4



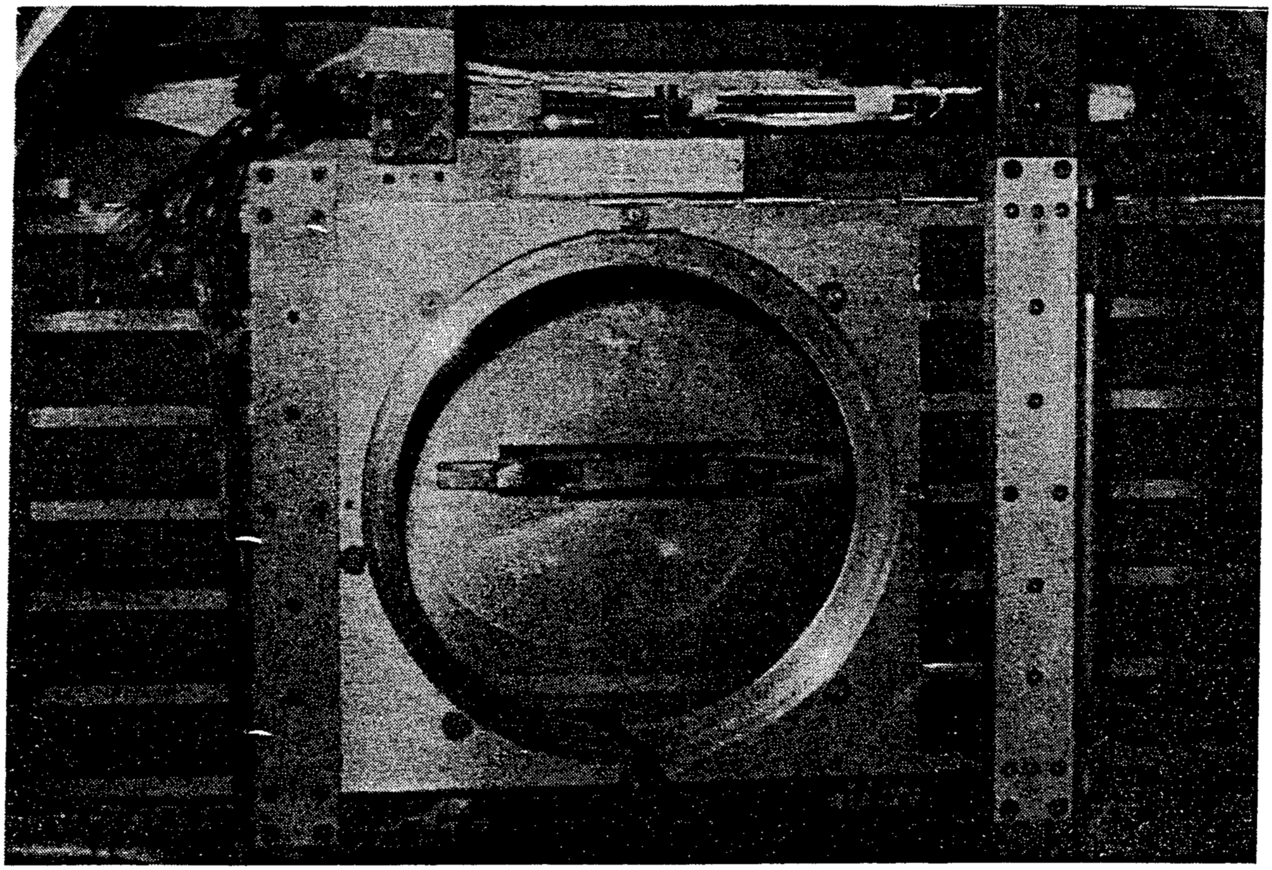
MODEL INSTALLATION ON OFFSET STING

Figure 5



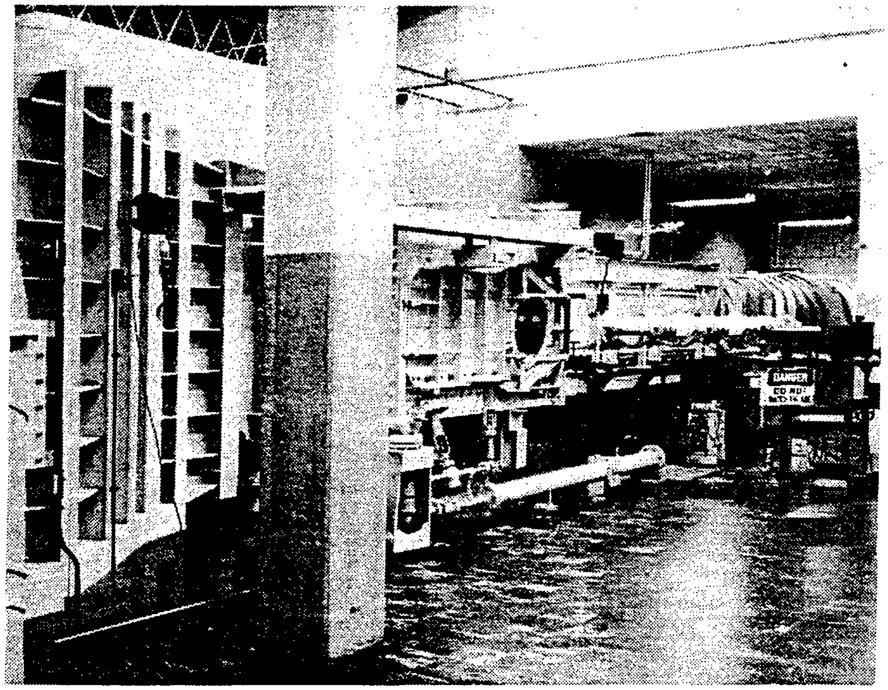
HALF-SPAN RIG

Figure 6



HALF SPAN MODEL INSTALLED IN TEST SECTION

Figure 7



TGF VIEW SHOWING TEST SECTION AND VARIABLE DIFFUSER

Figure 8

TRI-SONIC GASDYNAMICS FACILITY PERFORMANCE CHART FOR THE SUBSONIC TEST SECTION

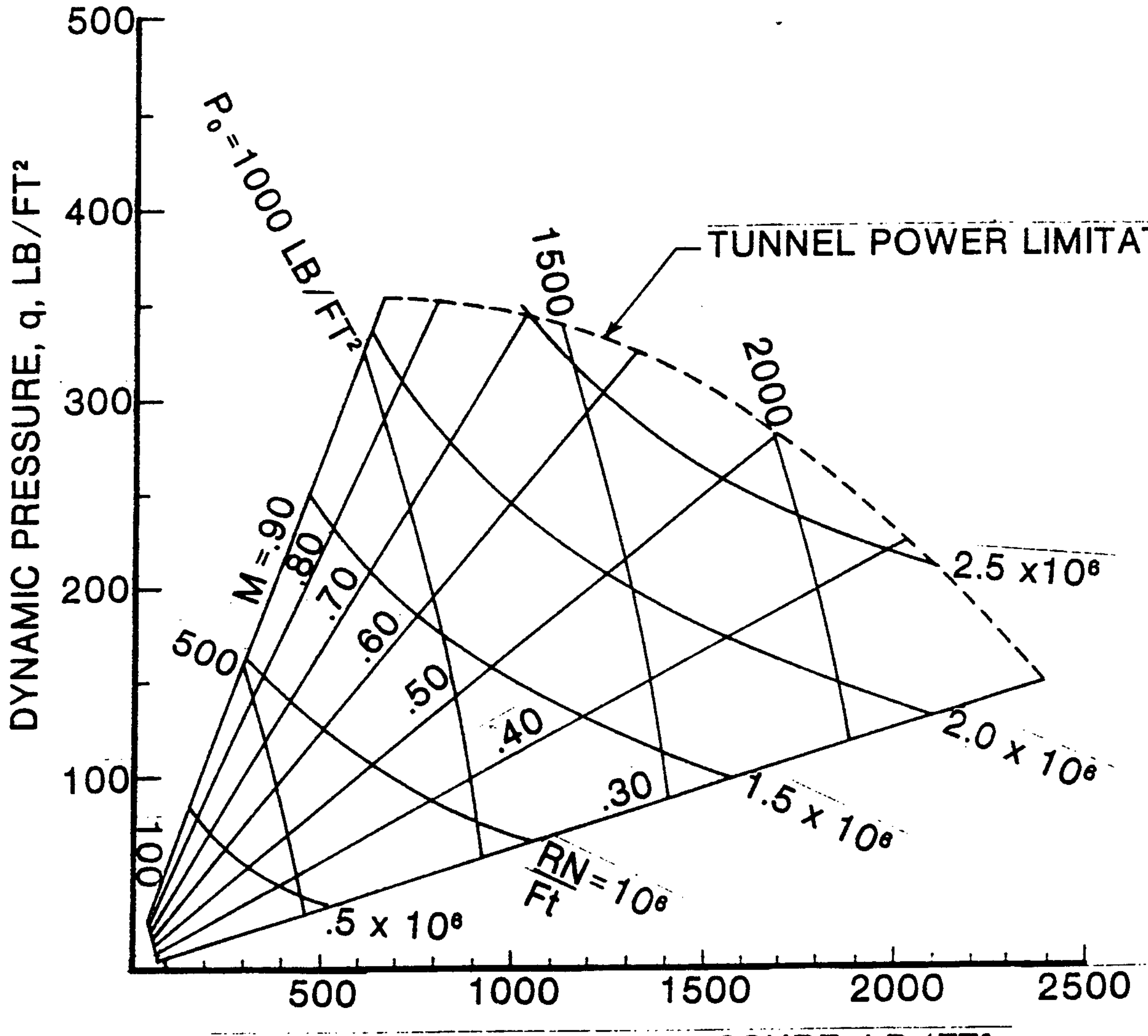


Figure 9

TGF SUBSONIC MASS FLOW

$\dot{W} = 0.02856\ M\ Po\ A/[To^{1/2}\ (1+0.2\ M^2)^3]$

$To = 559.6°R \quad A = 4FT^2$

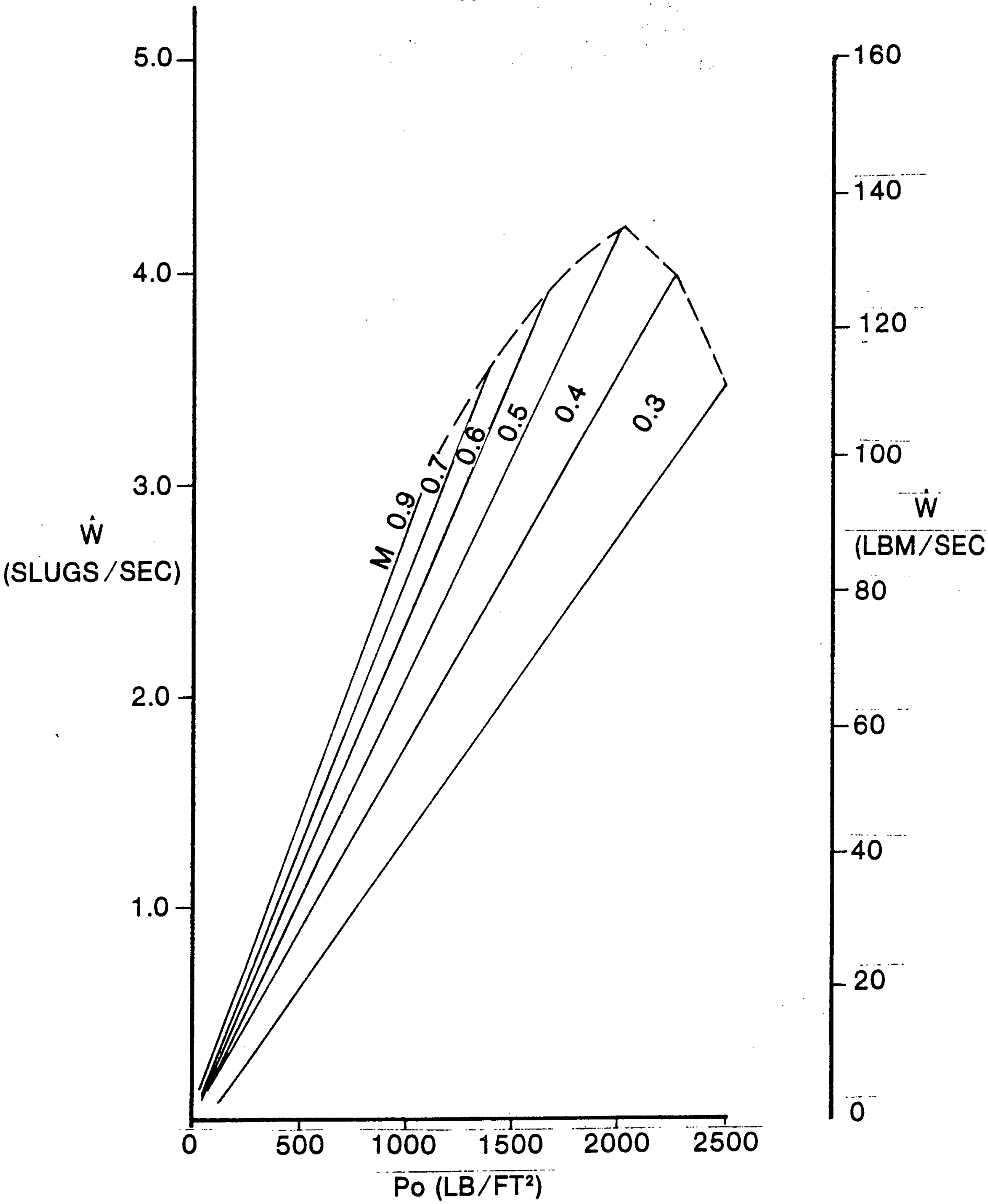


Figure 10

TRI-SONIC GASDYNAMICS FACILITY PERFORMANCE CHART FOR THE TRANSONIC TEST SECTION

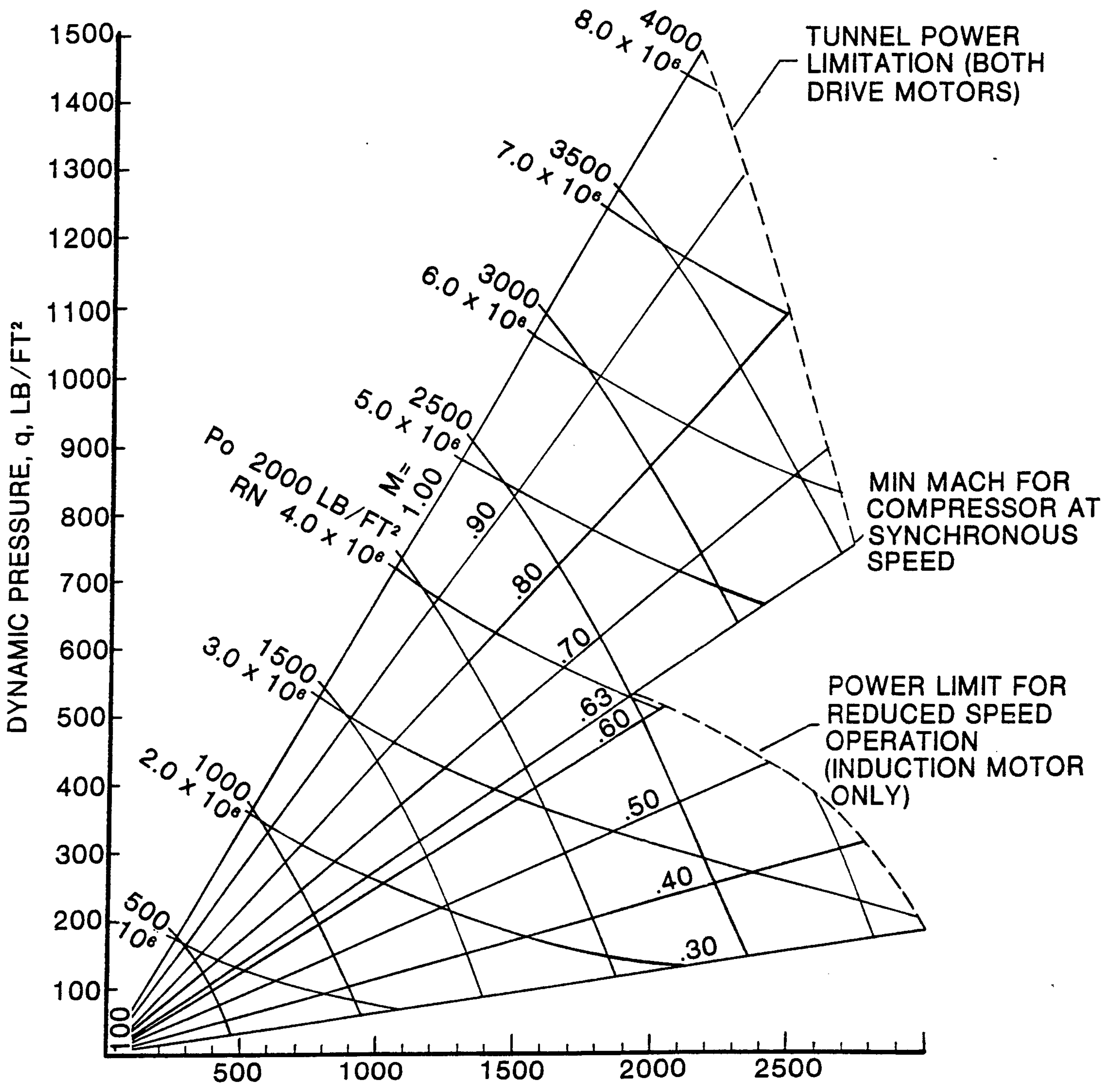


Figure 11

TGF TRANSONIC MASS FLOW

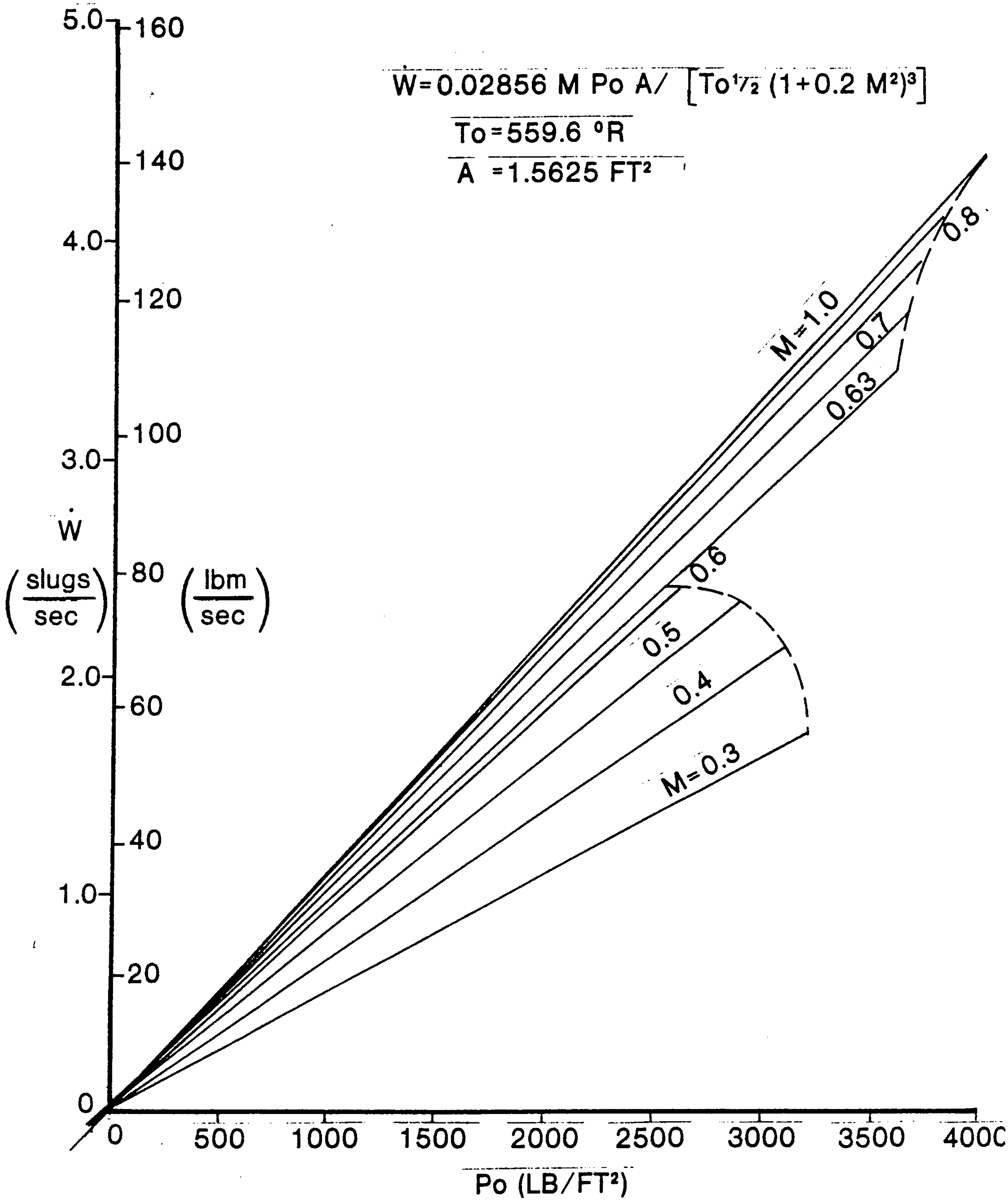


Figure 12

TRI-SONIC GASDYNAMICS FACILITY PERFORMANCE CHART FOR THE SUPERSONIC TEST SECTION

NOTE: THE TEST SECTION EMPLOYS FIXED NOZZLE BLOCKS AND OPERATES ONLY AT THE DESCRETE MACH NUMBERS INDICATED

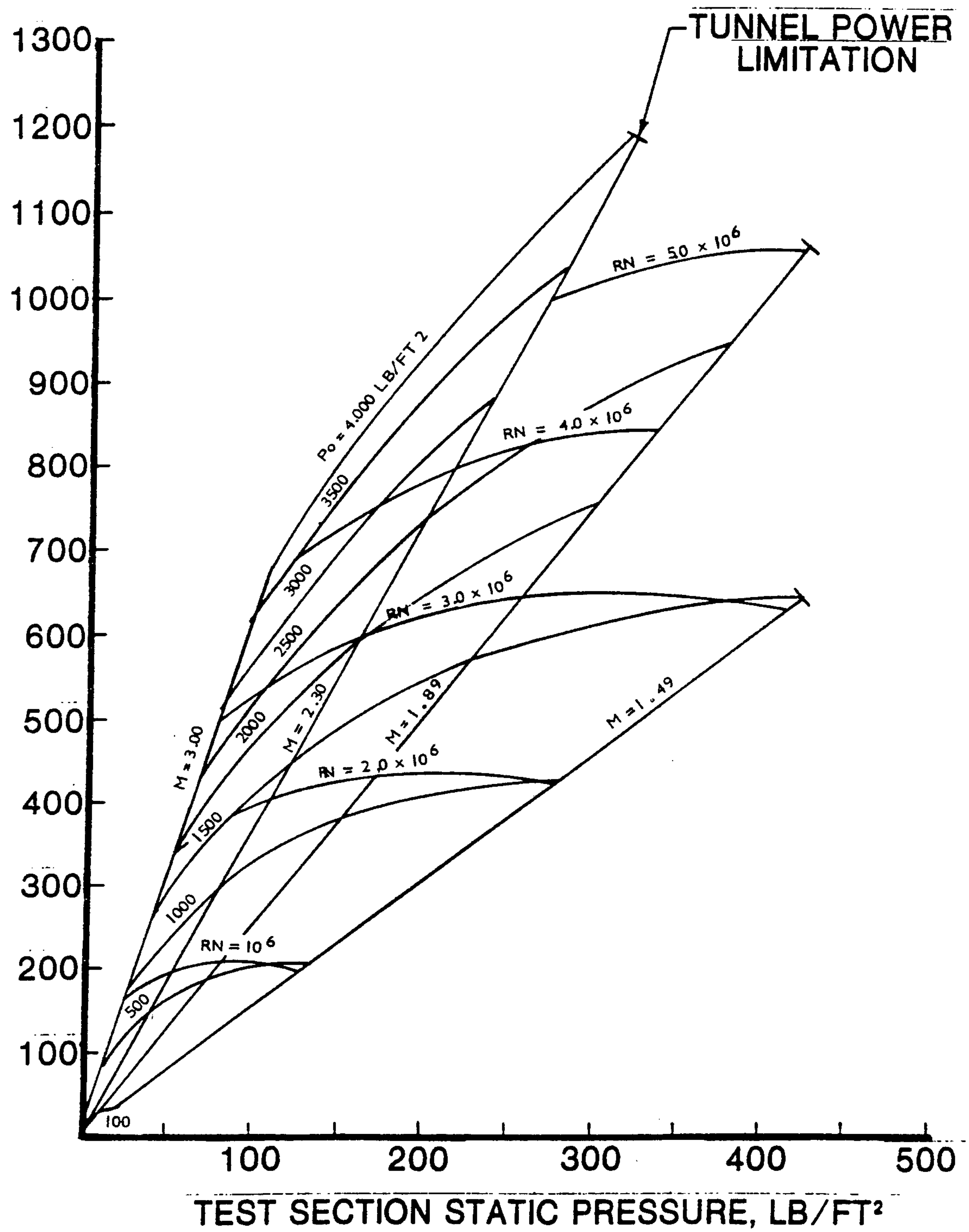


Figure 13

TGF SUPERSONIC MASS FLOW

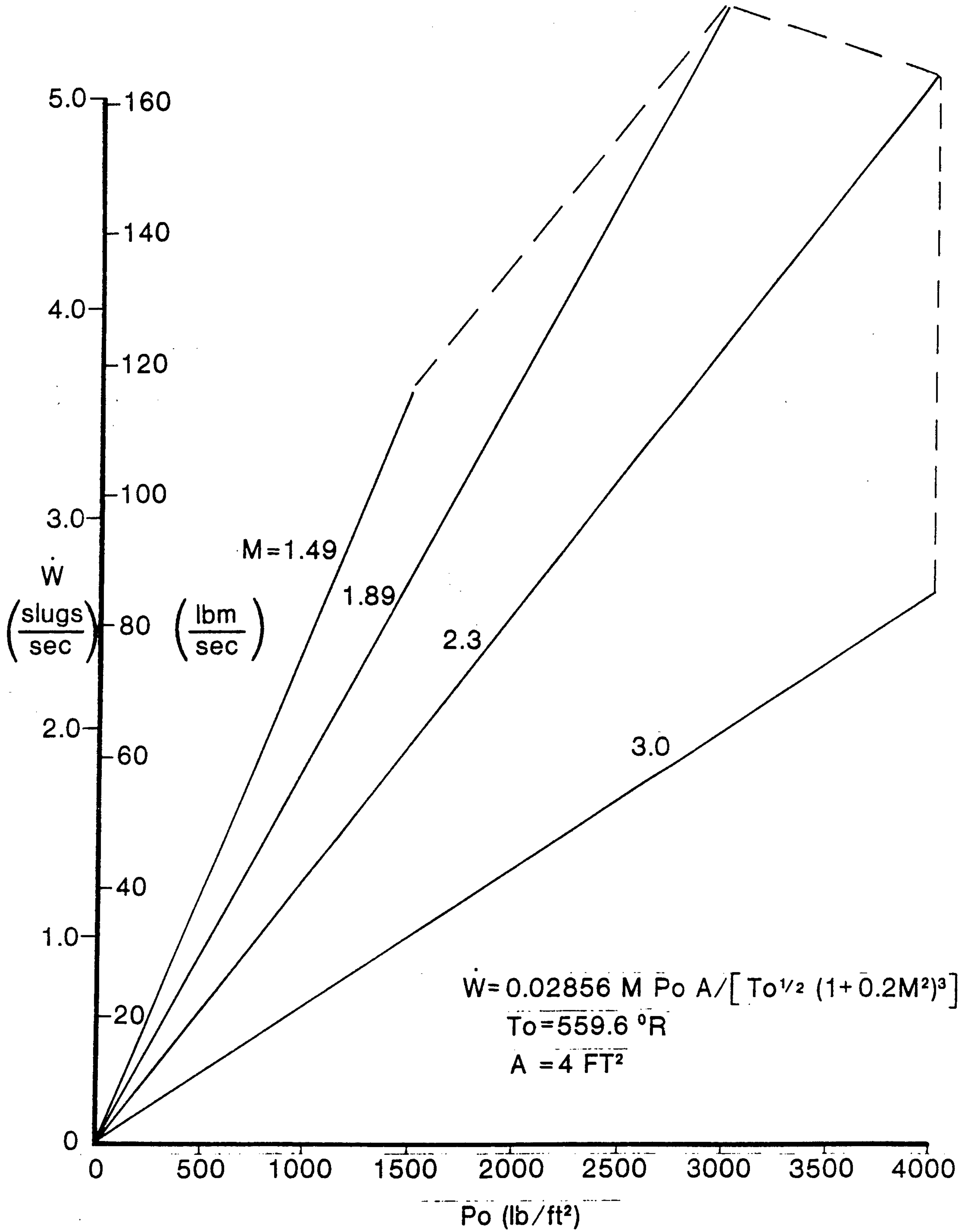
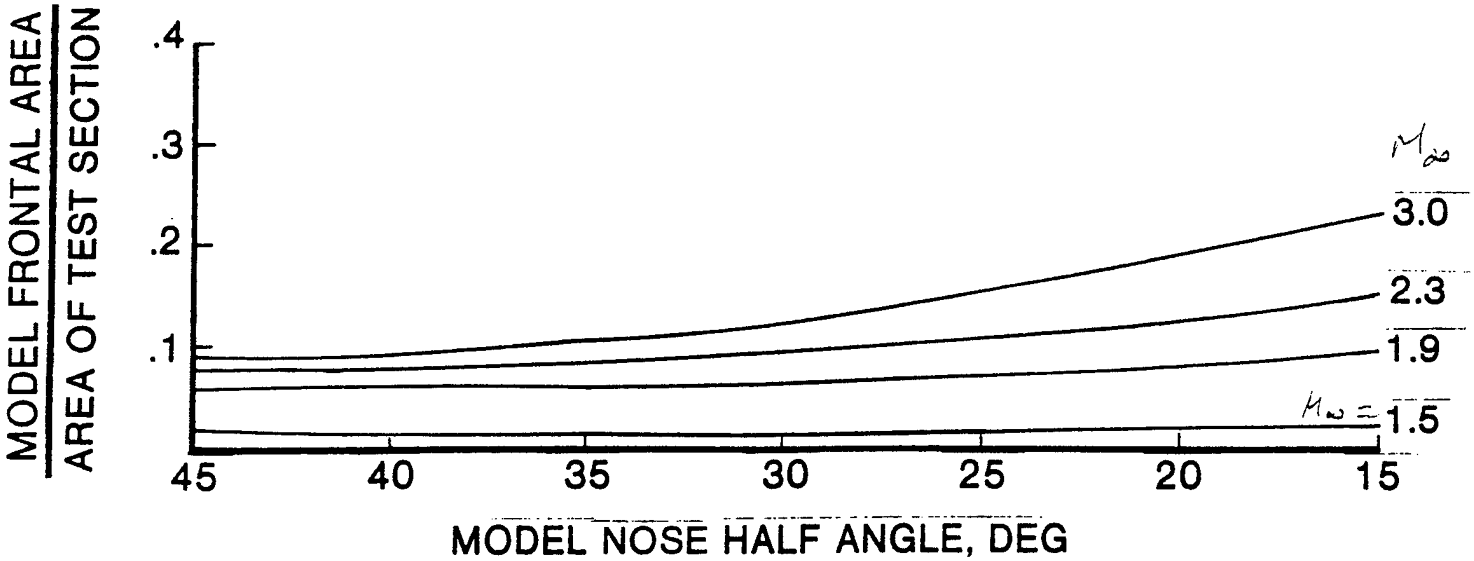


Figure 14

MODEL BLOCKAGE DATA
SUPERSONIC NOZZLE BLOCKS



CHOKING MACH NUMBER
SUBSONIC NOZZLE BLOCKS

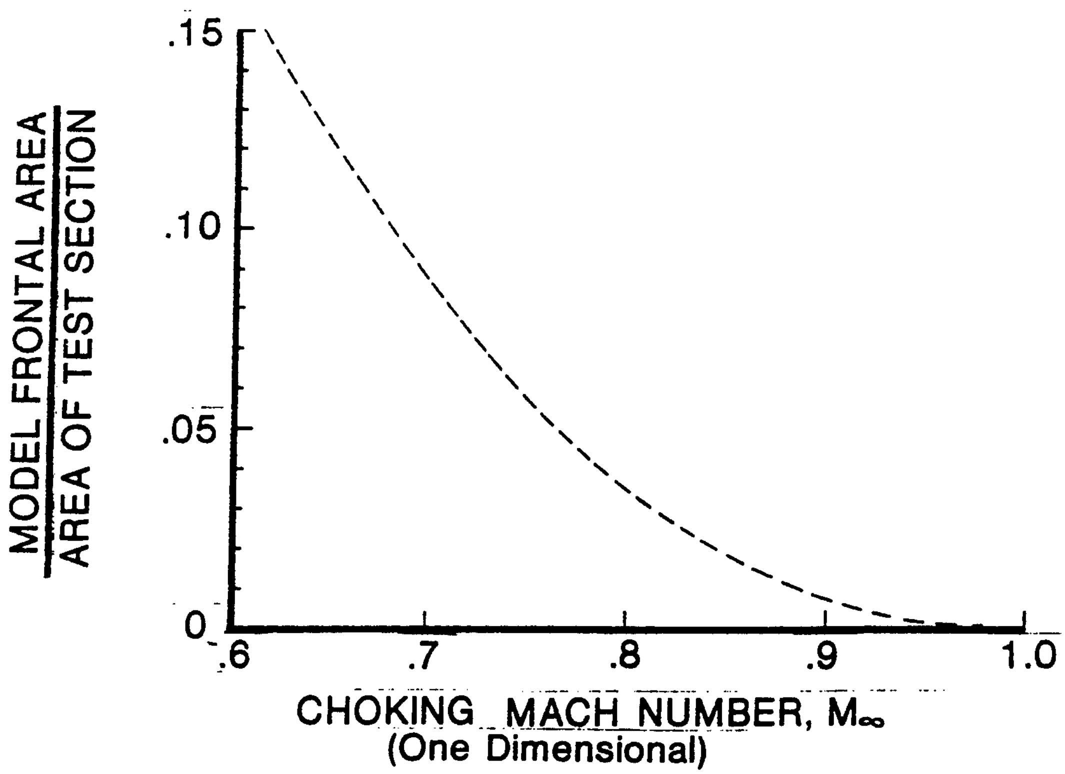


Figure 15

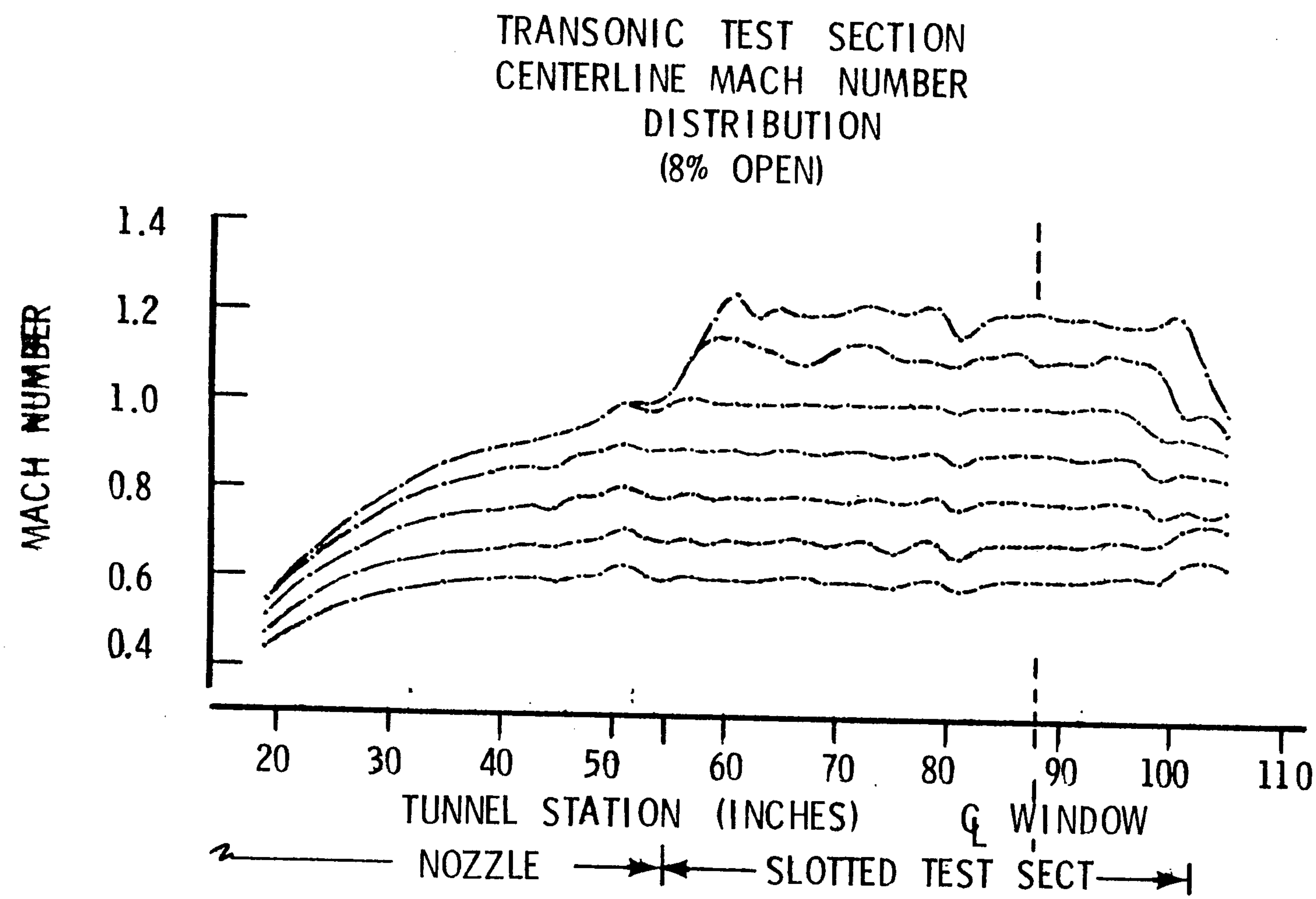
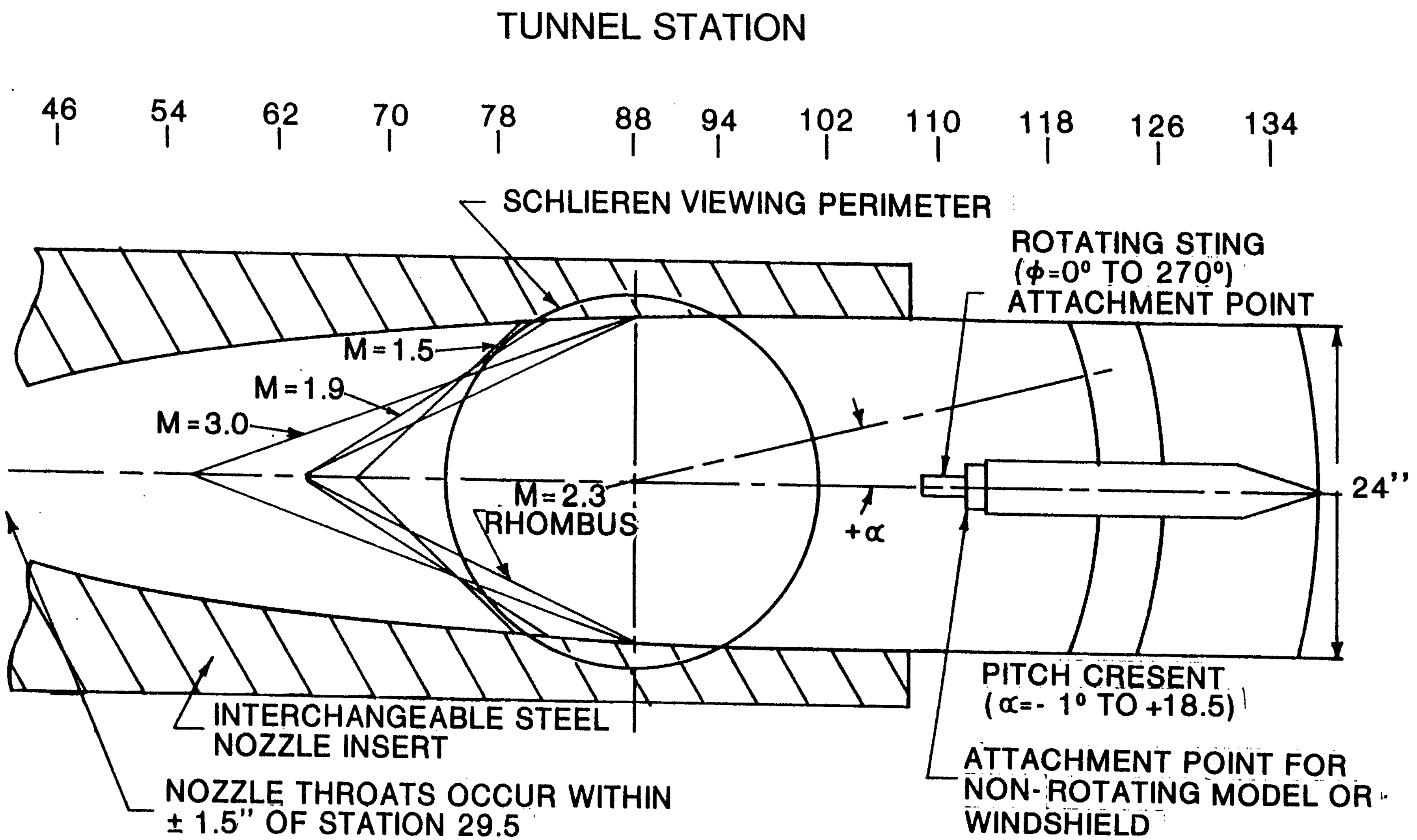

TRANSONIC TEST SECTION
CENTERLINE MACH NUMBER
DISTRIBUTION
(8% OPEN)
MACH NUMBER
1.4
1.2
1.0
0.8
0.6
0.4
20
30
40
50
60
70
80
90
100
110
TUNNEL STATION (INCHES)
℄ WINDOW
NOZZLE
SLOTTED TEST SECT

Figure 16



MODEL INSTALLATION REQUIREMENTS FOR THE TGF

Figure 17

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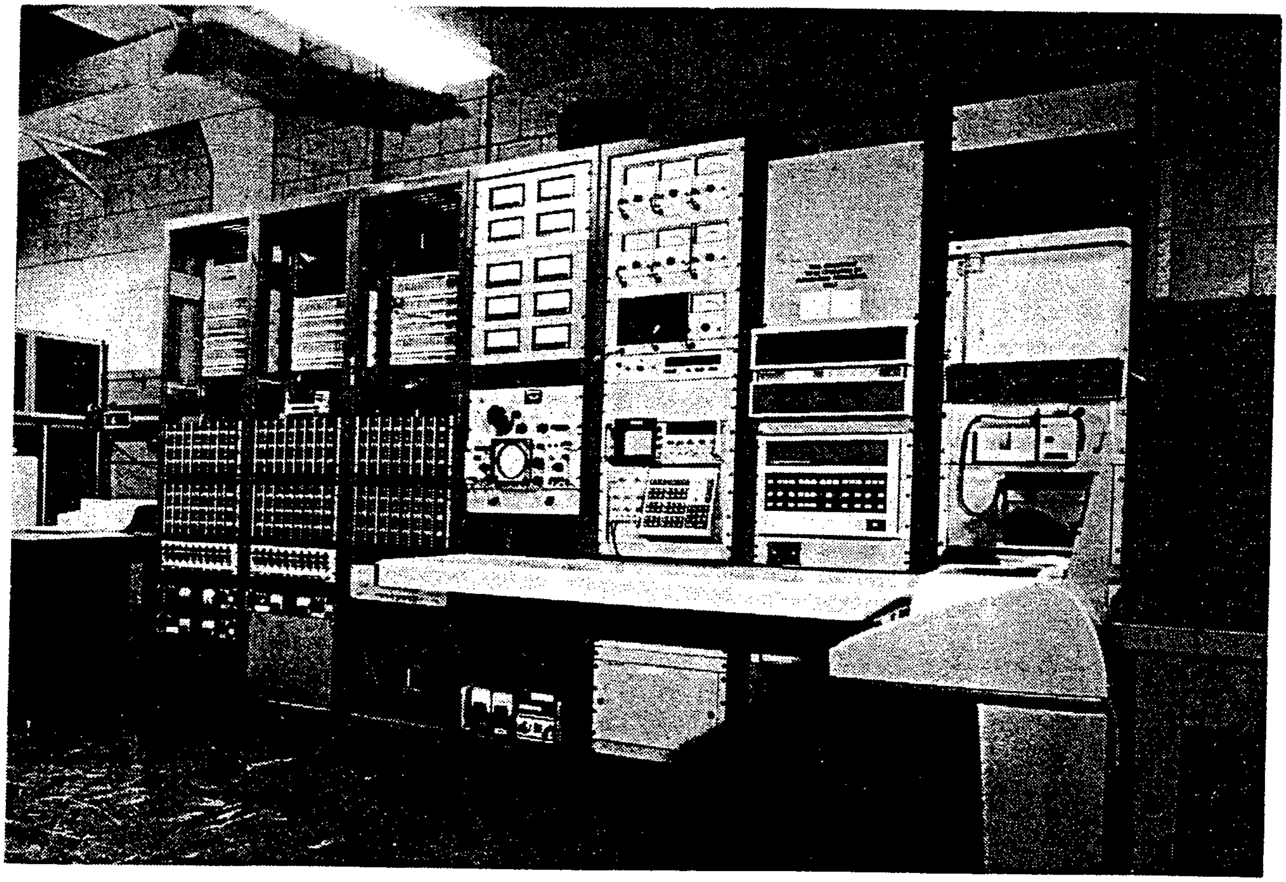
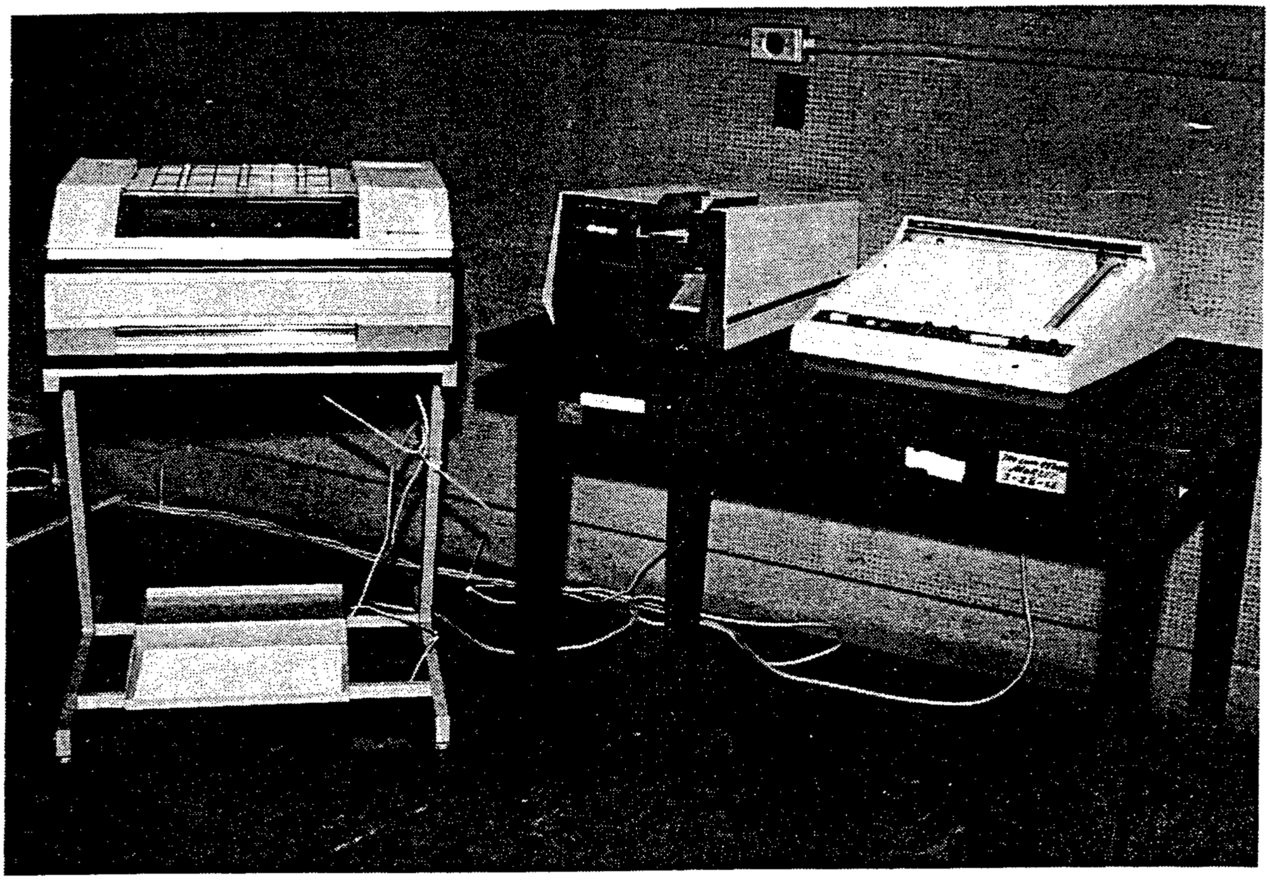


DATA REDUCTION SYSTEM

Figure 18



PRINTER, CARD READER, AND PLOTTER

Figure 19